Week – 4 – April 09, 2014

Application of Satellite Data to Particulate, Smoke and Dust Monitoring

Pawan Gupta

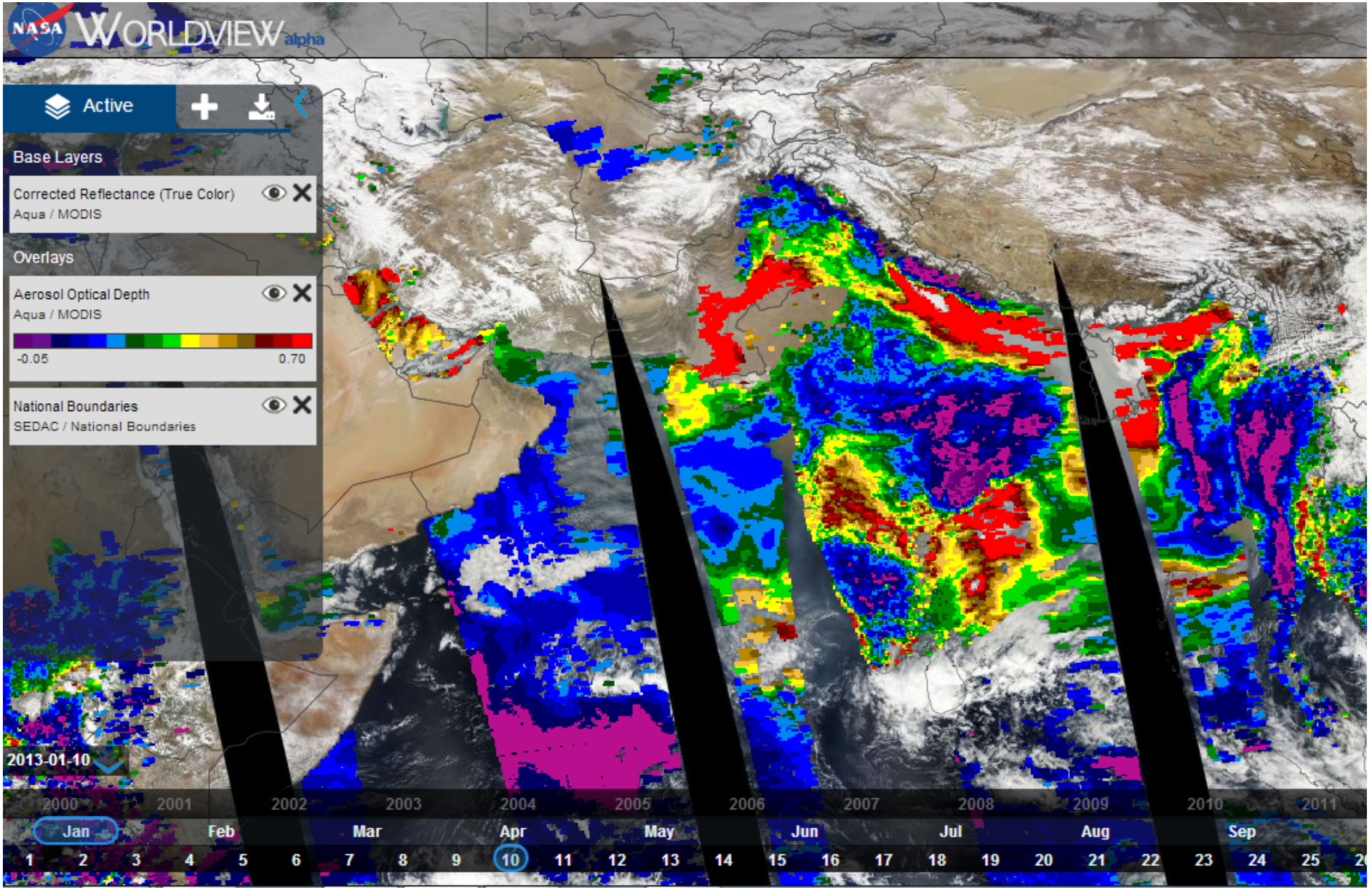
NASA ARSET- AQ On-line Short Course for Indian Region
Spring 2014

ARSET - AQ

Applied Remote Sensing Education and Training – Air Quality

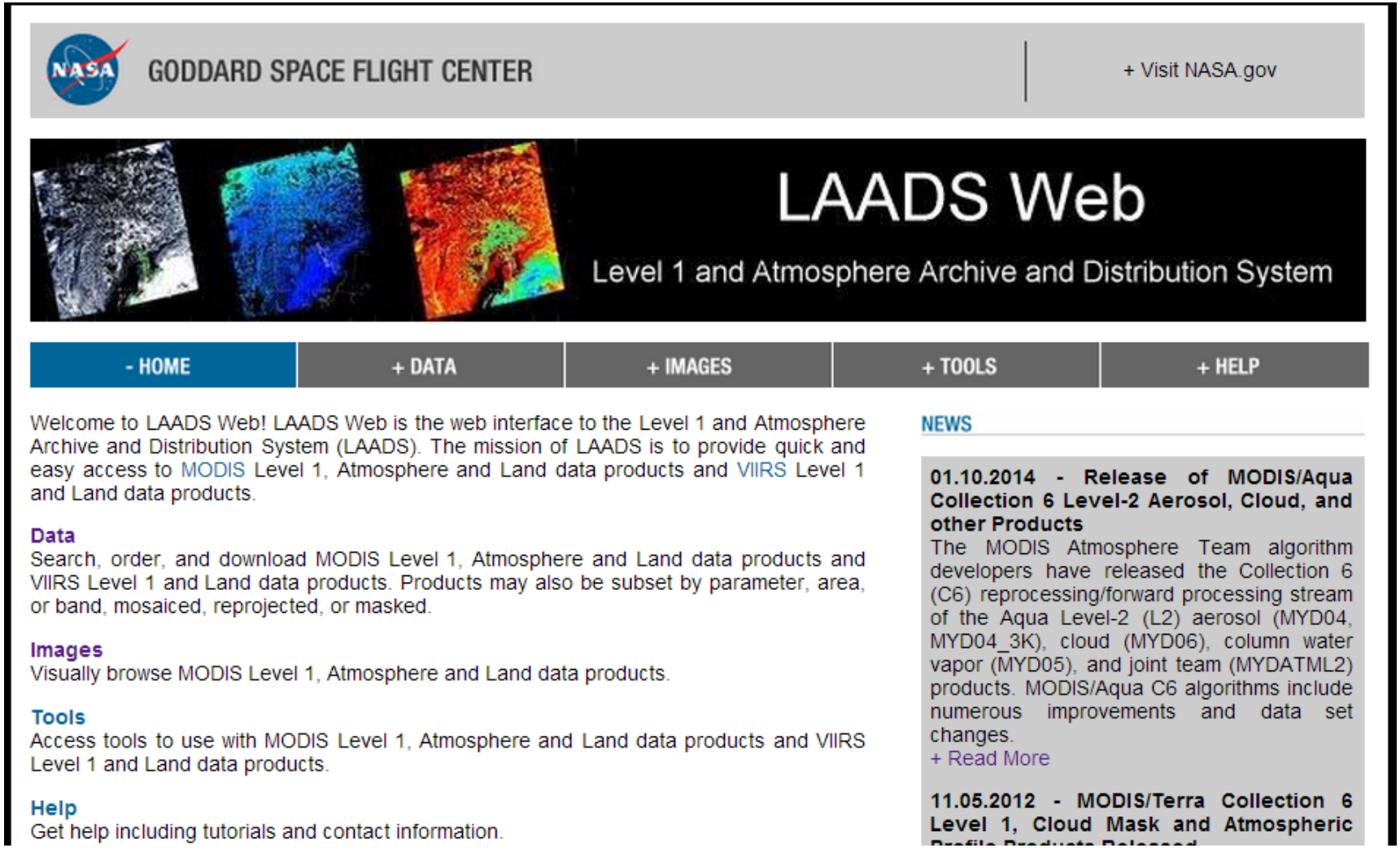
A project of NASA Applied Sciences

Revisiting Week 2 & 3

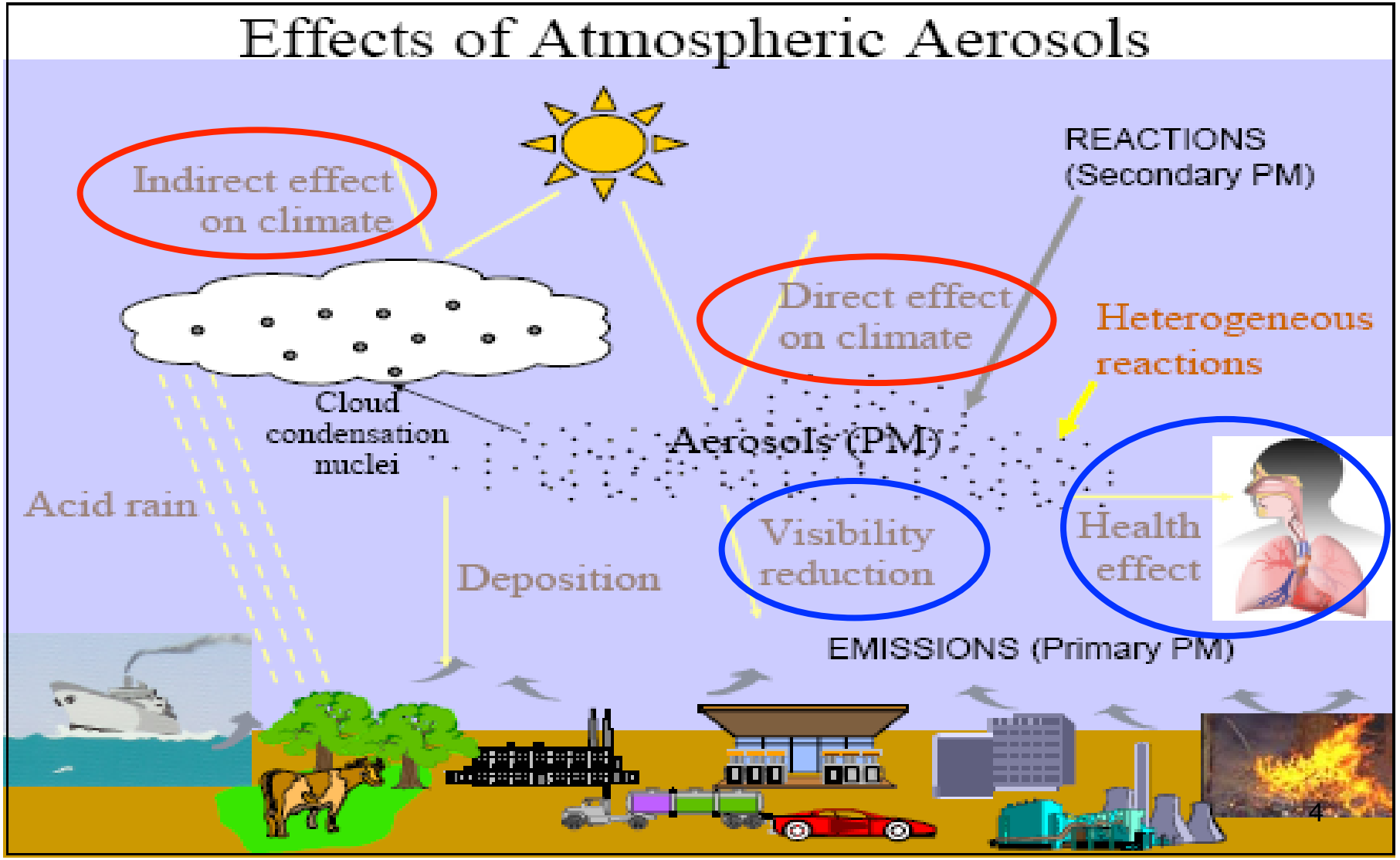


LADSWeb - Webtool to download MODIS data

http://ladsweb.nascom.nasa.gov/



Motivation – tiny but Potent



Environmental Agencies & Public Looking for…

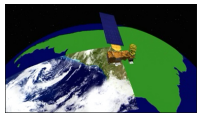
Index Values	Category	Cautionary Statements	$PM_{2.5}$ (ug/m^3)	PM_{10} (ug/m^3)
0-50	Good	None	0-15.4	0-54
51-100	Moderate	Unusually sensitive people should consider reducing prolonged or heavy exertion	15.5-40.4	55-154
101-150	Unhealthy for Sensitive Groups	Sensitive groups should reduce prolonged or heavy exertion	40.5-65.4	155-254
151-200	Unhealthy	Sensitive groups should avoid prolonged or heavy exertion; everyone else should reduce prolonged or heavy exertion	65.5-150.4	255-354
201-300	Very Unhealthy	Sensitive groups should avoid all physical activity outdoors; everyone else should avoid prolonged or heavy exertion	150.5-250.4	355-424

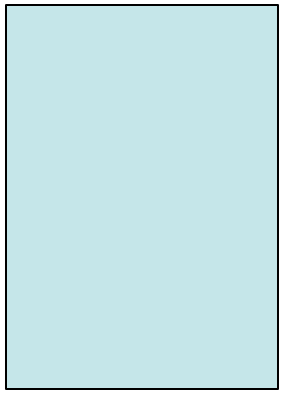
Guidelines **WHO**

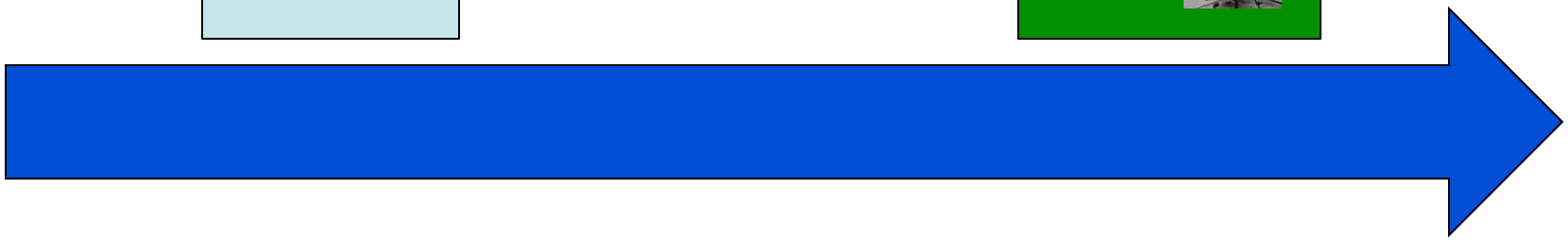
$PM_{2.5}$: 10 $\mu g/m^3$ annual mean
25 $\mu g/m^3$ 24-hour mean

India
40 μgm^{-3} – Annual mean
60 μgm^{-3} – 24 hour mean

- **Public**
- **Decision/Policy Makers**
- **Media**
- **Researchers**

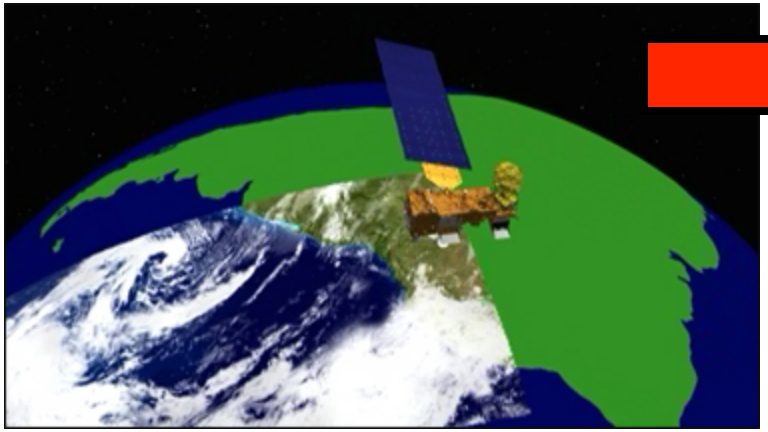






Column – to- Surface

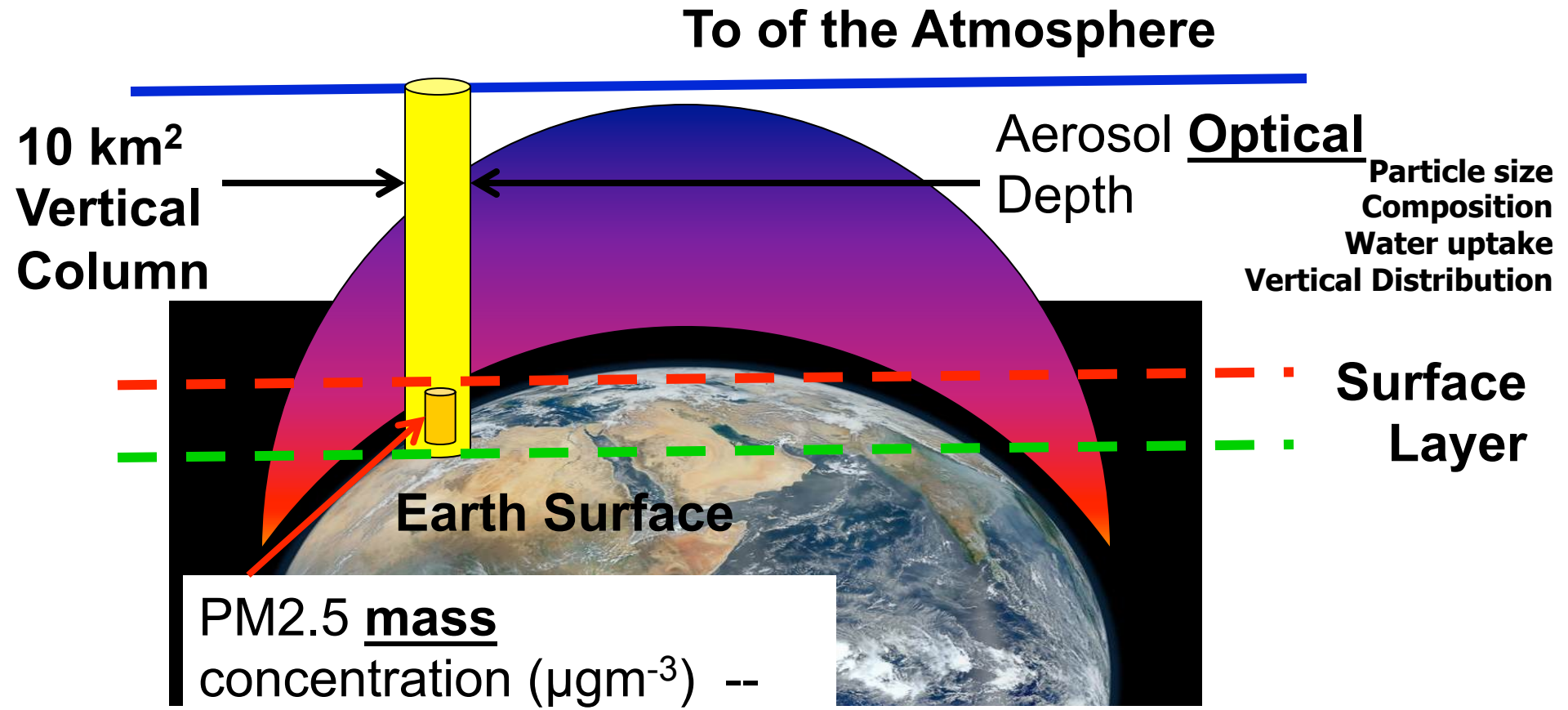
Measurement Technique



AOD – Column integrated value (top of the atmosphere to surface) - Optical measurement of aerosol loading – unit less. AOD is function of shape, size, type and number concentration of aerosols

PM2.5 – Mass per unit volume of aerosol particles less than 2.5 μm in aerodynamic diameter at surface (measurement height) level

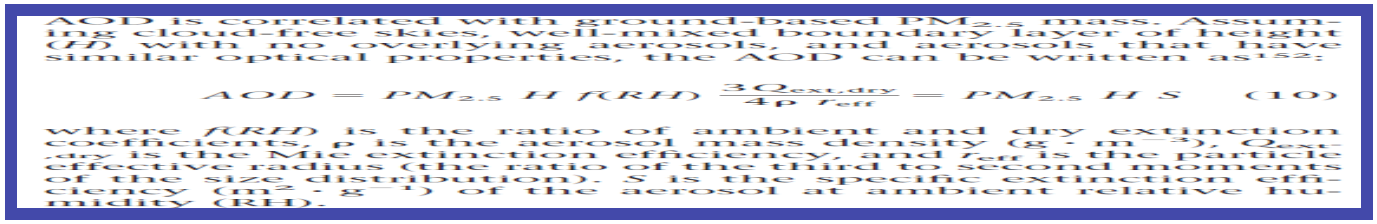
What is our interest and what we get from satellite?



Surface Particulate Measurements
vs
Satellite Measurements of Aerosols

- **Point vs Area Averaged**
- **Surface vs Column**
- **Mass vs Optical**

AOD to PM2.5 - Theoretical



AOD is correlated with ground-based $PM_{2.5}$ mass. Assuming cloud-free skies, well-mixed boundary layer of height (H) with no overlying aerosols, and aerosols that have similar optical properties, the AOD can be written as[152]:

$$AOD = PM_{2.5}\, H\, f(RH)\, \frac{3 Q_{extdry}}{4 \rho\, r_{eff}} = PM_{2.5}\, H\, S \qquad (10)$$

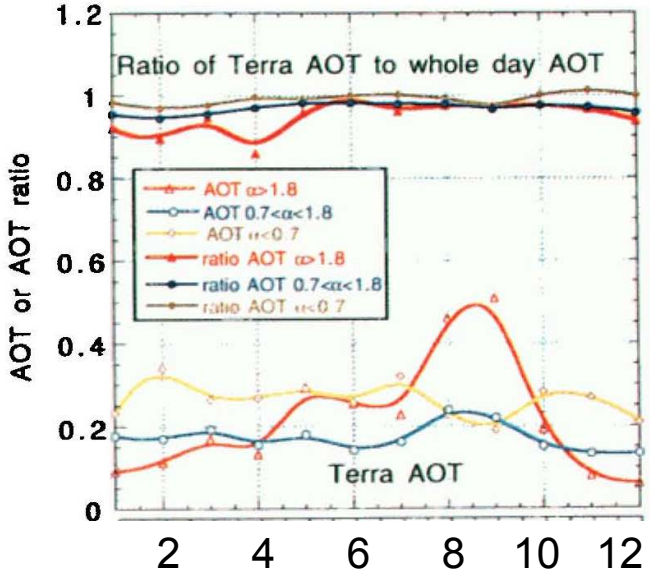
where $f(RH)$ is the ratio of ambient and dry extinction coefficients, ρ is the aerosol mass density ($g \cdot m^{-3}$), Q_{ext} is the Mie extinction efficiency, and r_{eff} is the particle effective radius (the ratio of the third to second moments of the size distribution). S is the specific extinction efficiency ($m^2 \cdot g^{-1}$) of the aerosol at ambient relative humidity (RH).

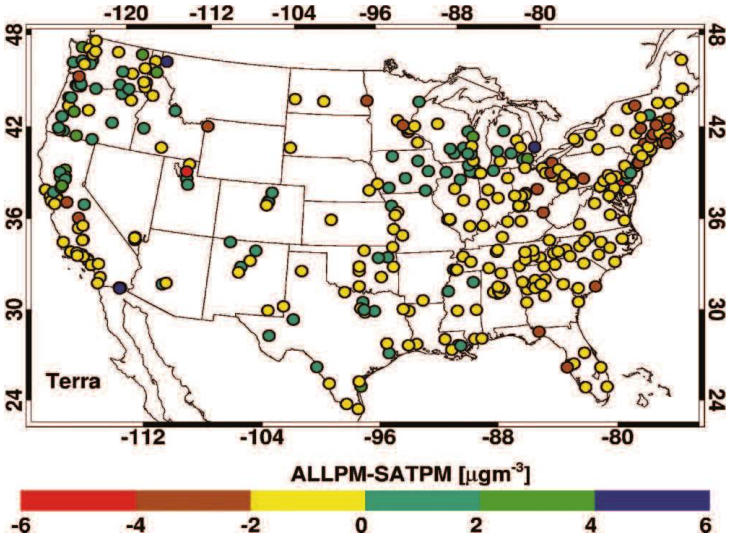
- AOD – Aerosol Optical Depth
- H – Height of well-mixed boundary layer
- f(RH) – ratio of ambient and dry extinction coefficients
- p – aerosol mass density
- Q – Mie extinction efficiency
- r – particle effective radius
- PM2.5 – PM2.5 mass concentration

Hoff and Christopher, 2009

Support for AOD-$PM_{2.5}$ Linkage

- Current satellite AOD is sensitive to $PM_{2.5}$ (Kahn et al. 1998)
- Polar-orbiting satellites can represent at least daytime average aerosol loadings (Kaufman et al., 2000)
- Missing data due to cloud cover appear random in general (Christopher and Gupta, 2010)





AOD-PM Relationship

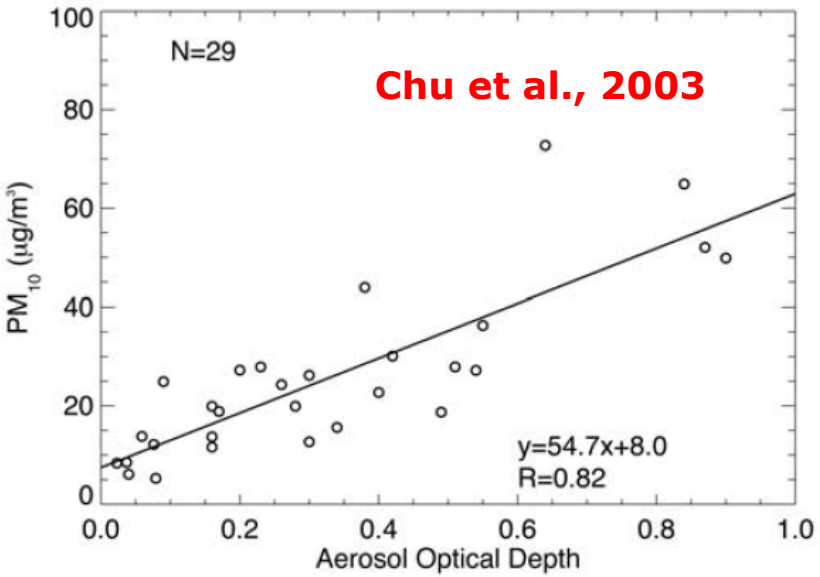
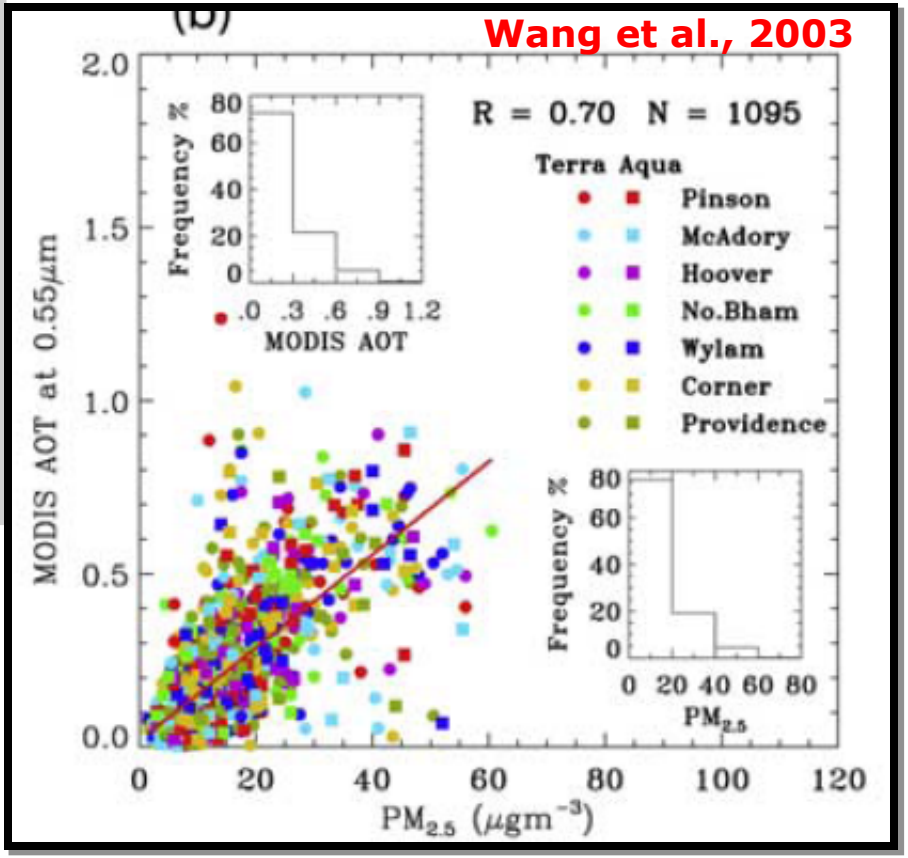


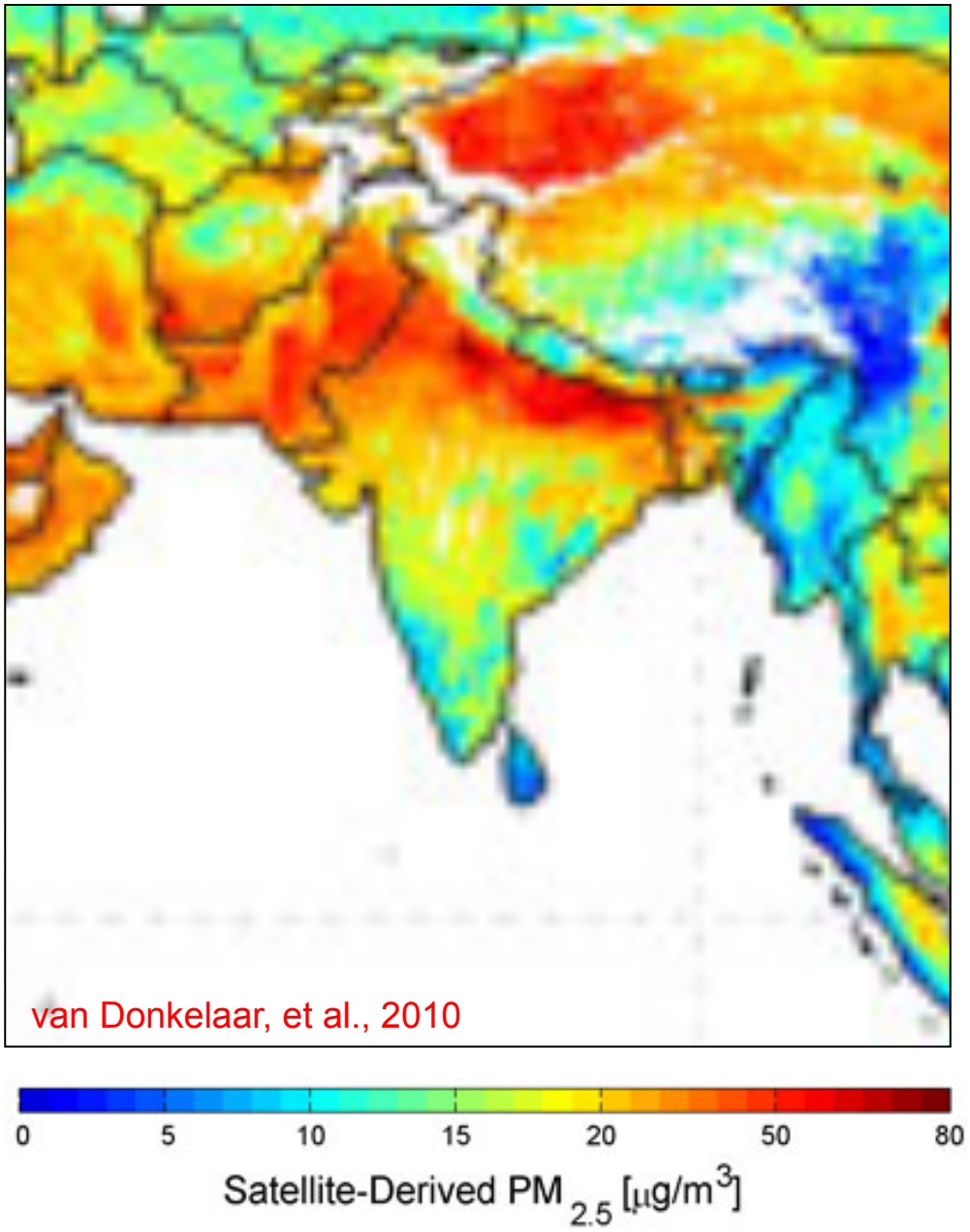
Figure 14. Relationship between 24-hour PM_{10} concentrations and daily averaged AERONET τ_a measurements from August to October 2000 in northern Italy.



Questions to Ask: Issues

- ✓How accurate these estimations are ?
- ✓Is PM2.5-AOT relationship is always linear?
- ✓How does uncertainty in AOT retrieval impact estimation of air quality
- ✓Does this relationship changes in space and time?
- ✓Does this relationship changes with change in aerosol type?
- ✓How meteorology drive this relationship?
- ✓How about vertical distribution of aerosols in the atmosphere?

Satellite can provide spatial coverage, which is very difficult to get from ground based network



Assumption for Quantitative Analysis

When most particles are concentrated and well mixed in the boundary layer, satellite AOD contains a strong signal of ground-level particle concentrations.

Modeling the Association of AOD With $PM_{2.5}$

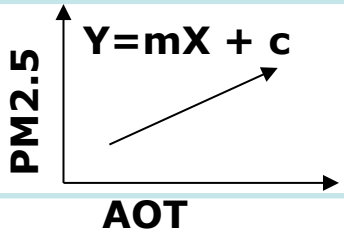
- The relationship between AOD and $PM_{2.5}$ depends on parameters hard to measure:
  - Vertical profile
  - Size distribution and composition
  - Diurnal variability
- We develop statistical models with variables to represent these parameters
  - Model simulated vertical profile
  - Meteorological & other surrogates
  - Average of multiple AOD measurements

No textbook solution!

PM2.5 Estimation: Popular Methods

Difficulty Level

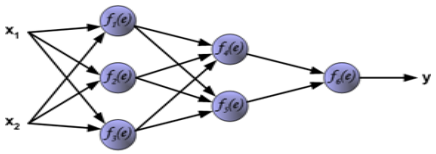
Two Variable Method



Multi-Variable Method

$$PM2.5 = \beta_0 + \alpha * \tau + \sum_{n=1}^{m} (\beta_n * M_n)$$

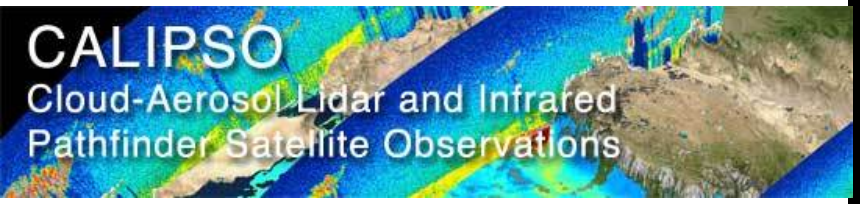
Artificial Neural Network

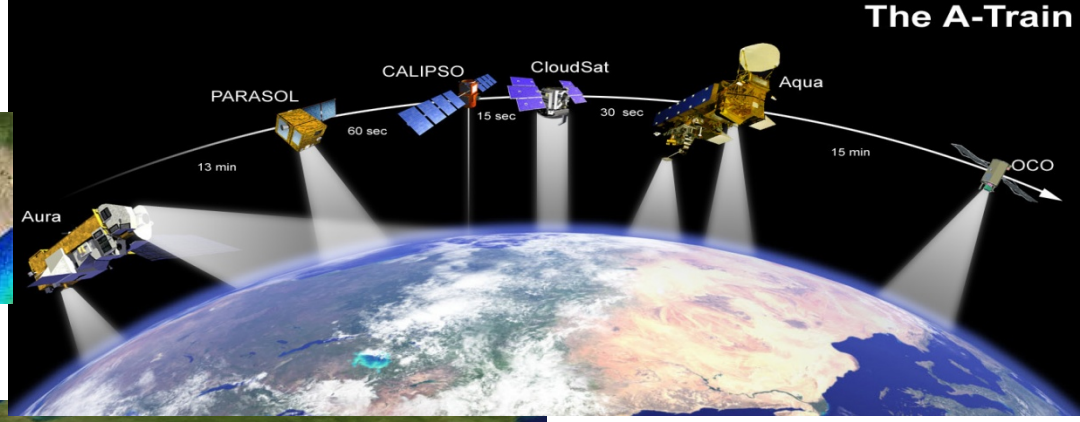


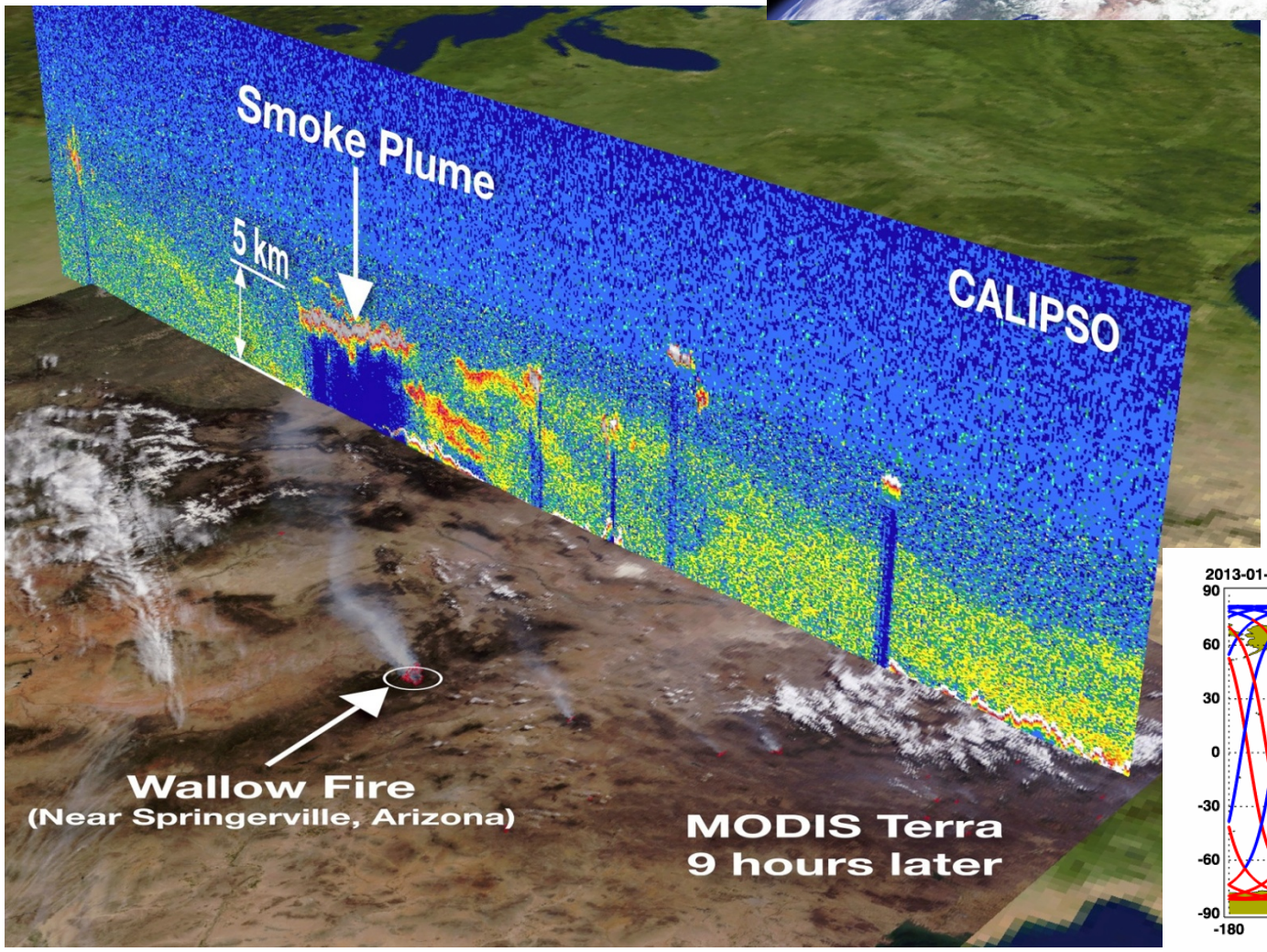
MSC

$$Estimated\ PM_{2.5} = \frac{Model\ surface\ aerosol\ concentration}{Model\ AOD} \times Retrieved\ AOD$$

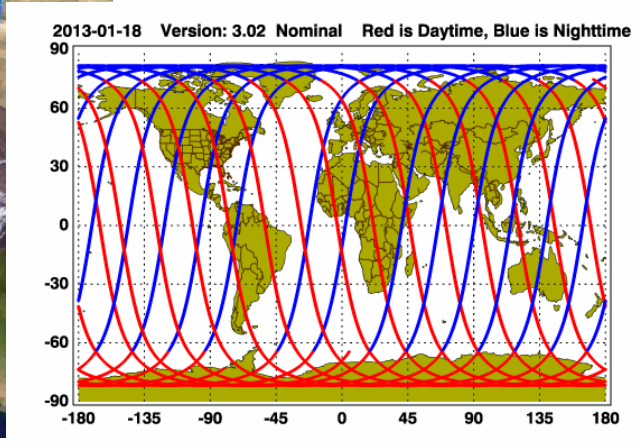
and Empirical Methods, Data Assimilation etc. are under utilized







What Satellites can provide for vertical information? - CALIPSO



2009 CRITICAL REVIEW

ISSN:1047-3289 J. Air & Waste
DOI:10.3155/1047-3289.59.6.
Copyright 2009 Air & Waste Manage

R.M. Hoff

S.A. Christopher

Remote Sensing of Particulate Pollution
from Space: Ha
Promised Land

Raymond M. Hoff
Department of Physics and the Joint Center for Earth Systems Tec
and Technology Center, University of Maryland
th Sciences

Sundar A.

The use of the AOD as a measure for mass concentration has skill in some regions but less in others and does not provide a uniform way to measure aerosols across the United States. We discussed in Table 4 the range of mea-

dards (NAAQS).[142] The 39-yr history of those standards parallels the time period that satellite meteorology and observations have developed and yet, to date, no satellite measurements have been used to quantitatively address the NAAQS. From the review conducted here, only one congres-

IMPLICATIONS

Satellite measurements are going to be an integral part of the Global Earth Observing System of Systems. Satellite measurements by themselves have a role in air quality studies but cannot stand alone as an observing system. Data assimilation of satellite and ground-based measurements into forecast models has synergy that aids all of these air quality tools.

EPA has taken a satellite observations role for itself in the Exceptional Events Rule.[144] If a region can show conclusively that they are being impacted by an event (a fire, a dust storm, etc.) that is outside of their jurisdiction to regulate, the event can be flagged as a nonexceedance event. This provides a significant motivation for regional

ellite data possible in significant exceedances only. Applications such as event identification, transport, and atmospheric composition determination are strengths of satellite measurements. Where high precision is required (compliance monitoring, the "but for" test, and quantitative measurement of visibility effects on Class I areas), satellite data are presently of limited utility.

Although the desire for the use of satellite data for air quality purposes is widely stated, the reality is that many of the measurements have not yet met the promise that they can be operationally used for today's air quality monitoring requirements. Precision in measuring AOD is

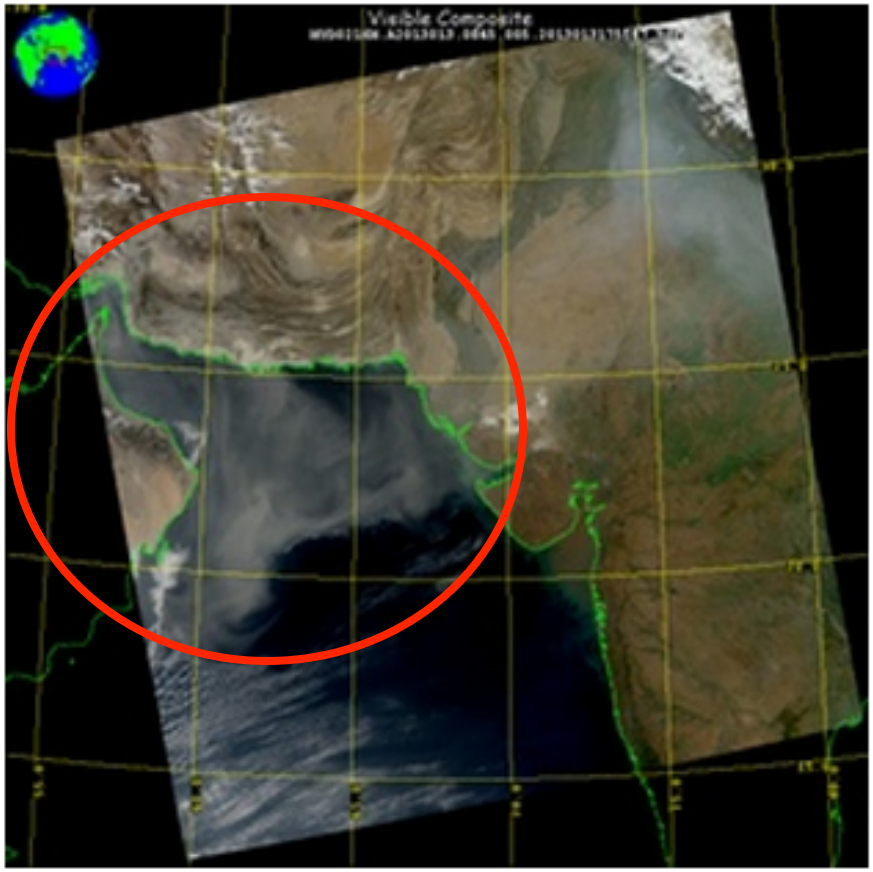
Suggested Reading

Dust & Smoke Monitoring Resources

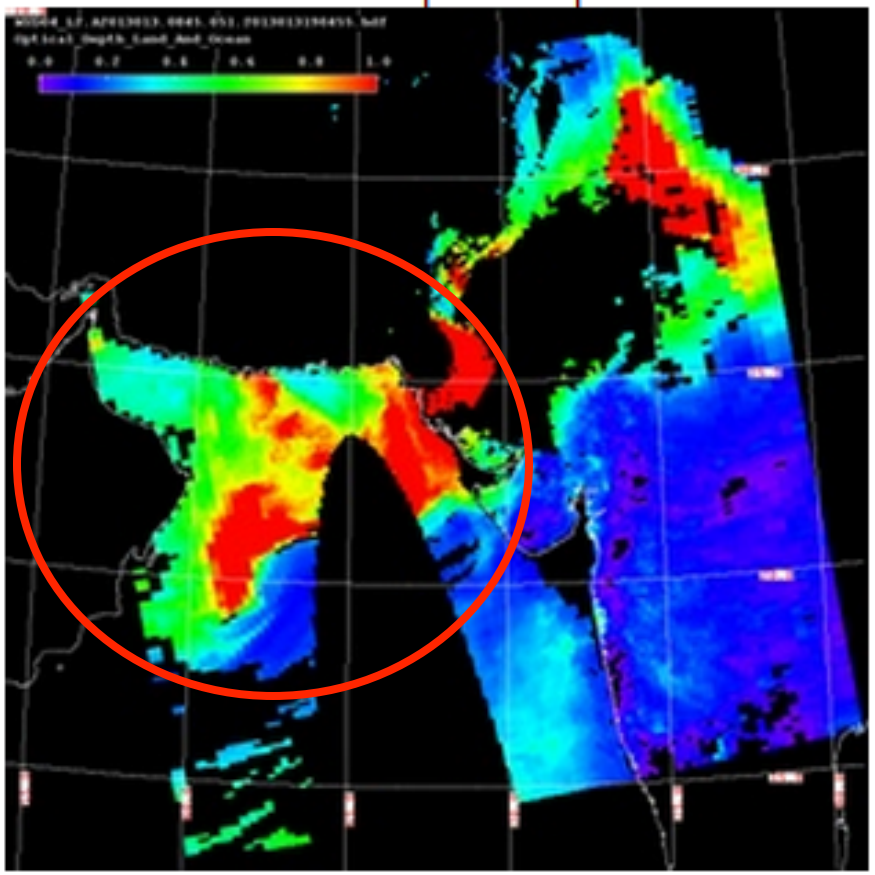
- **RGB Images**
- **Aerosol Optical Depth**
- **Aerosol Index (OMI, OMPS)**
- **MISR coarse/fine mode AOD**
- **AIRS Dust Score**
- **AIRS CO**
- **AERONET**

Dust over Arabian Sea

RGB



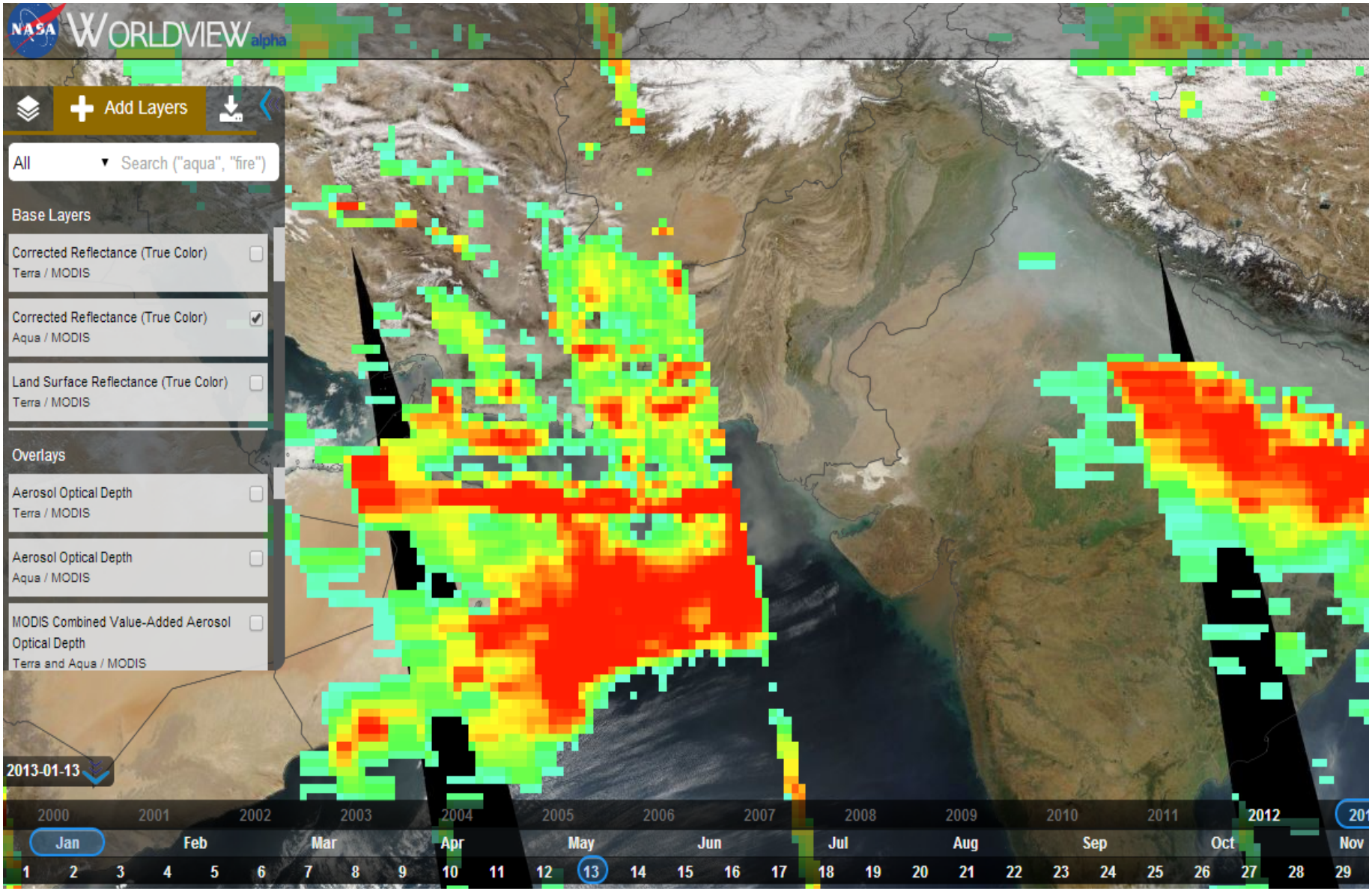
Aerosol Optical Depth



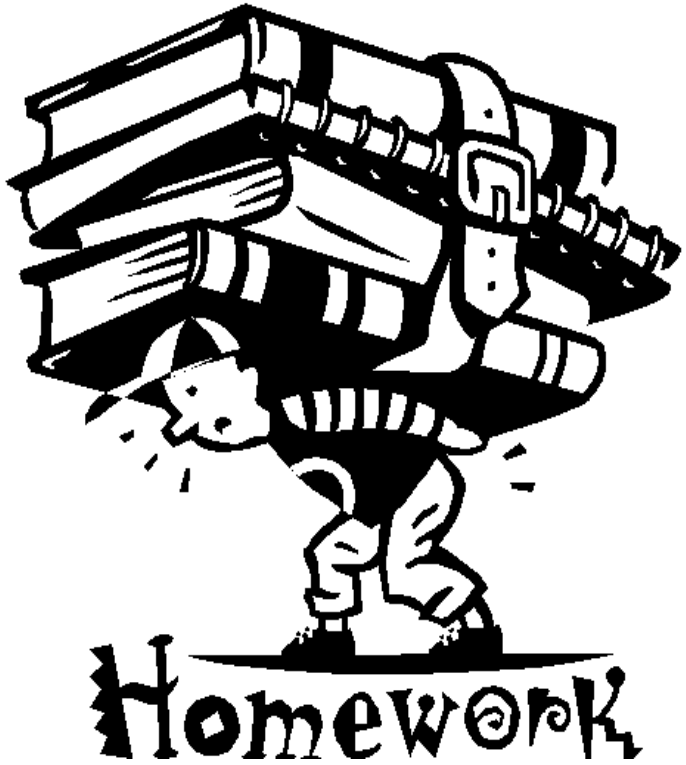
Created using LADSWeb

http://ladsweb.nascom.nasa.gov/browse_images/granule_browser.html?form=AADS&browseType=Granule

Dust – Aerosol Index



Assignment – Week 4



https://docs.google.com/forms/d/1xysKBhJWtlMaGWOa2qQzj2c1BzQp-Nz8Z61aU4ftUZE/viewform